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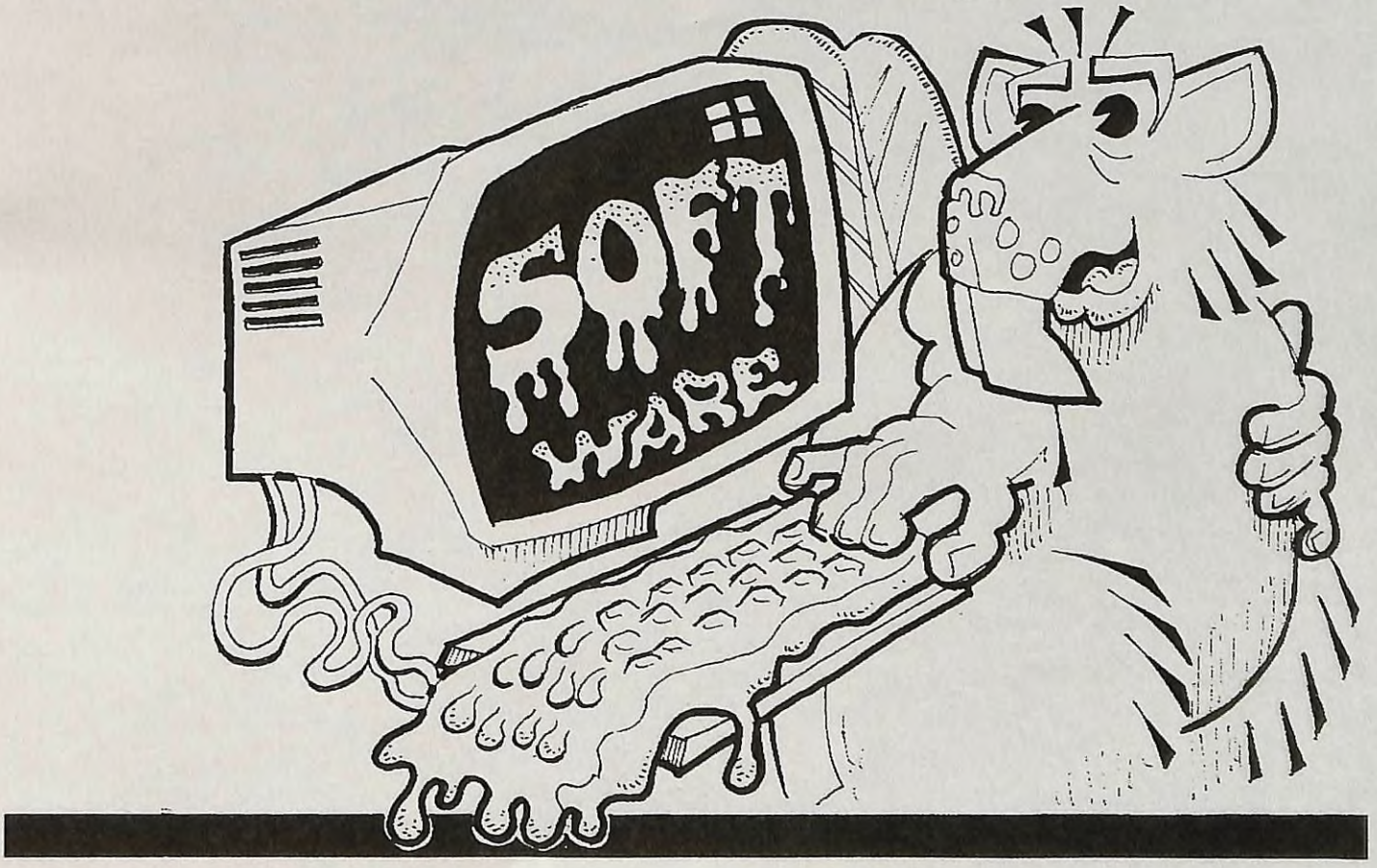
Energy Software



From the Editor . . .

Codes and standards are important. They set out appropriate minimum safety and performance levels for materials, appliances and equipment. In Canada, there are a number of bodies that define standards. Some are government agencies, such as the Canadian Codes Centre at the National Research Council and the Canadian Government Standards Board (CGSB); others are independent industry supported agencies, such as the Canadian Standards Agency (CSA) or the Underwriters Laboratories (UL). These are the most well known agencies, but there are others as well.

The CSA mark is easy to recognize and has been around since 1919. But what does a CSA mark really mean? Is the approach CSA takes in the development and management of standards adequate, or is it tilted in favour of the manufacturers who are the mainstays of each committee? Decisions are made by consensus, so decisions that challenge the status quo may not be made easily. Innovators with new ideas could have a hard time breaking through the barriers of existing standards, no matter how technically sound their ideas may be.

It seems to me that the privatized, cost recovery approach that CSA relies on is not able to properly deal with all issues that need to be considered when a standard is set. Committee participation is done on a voluntary basis and favours participation from large corporate entities based in Central Canada, making it difficult for people from other regions of the country to participate. Occasionally an industry group or government agency will add funds to help develop or update a standard. Since most funding comes from the sale of standards, prices are set quite high so sales tend to be small. Most people who should have a copy do not have one and may not even be aware of its content.

I think it may be appropriate to review how well the current standards system is working. My thoughts have been spurred on by a review of a number of CSA standards, and changes that have been made recently.

For example, the CSA window standard defines criteria for product compliance, but products that technically meet the standard don't really reflect the products on the market. And there is no assurance that products in the marketplace with the CSA mark could actually pass the tests set out in the CSA standard. Similarly, the standard for toilets seems to accept toilets that don't work. Changes have recently been made to the electrical standard - which is the electrical code in Canada. However, CSA did not bother to let a significant segment of users know what changes were being contemplated. One of the changes introduced a requirement that calls for the use of an electric breaker that may not work

One problem may be that the standards don't necessarily require ongoing verification of compliance. Once a product has been tested, usually based on a manufacturer-prepared prototype sample, it gets certification for life. Testing is seldom done on products off the assembly line but on specially prepared samples, so examples of real life product are not tested. There is little follow-up to ensure that the products actually in production continue to meet the standard.

It is also worth considering to whom the CSA standards committees are accountable. The development of the Building Code is an open process, accessible by all code users. In contrast, changes in CSA standards seem to happen in secrecy or at least are only known to a small group of insiders. Although comments are welcomed, they are not solicited, and outsiders have to know something is happening or is in the works to be able to make those comments.

It may only be a problem with the CSA process. However, I suspect that similar issues may apply to other standards agencies, and unfortunately too many of us who rely on them are not fully aware of the scope of their activity or purposes.

Richard Kadulski, Editor

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Energy Software for the Building Industry

Computer software has improved tremendously over the past few years. Twenty years ago, the capabilities of any computer were limited. Computers were rarely used for functions other than basic mathematical calculations. If builders and designers used computers at all, it was mostly for simple business functions like accounting and possibly word processing. Today, most of us rely on computers for much more, including keeping in touch with family and friends in all parts of the world.

In the 1970s, calculating heat loss accurately was time consuming because it had to be done by hand. Older publications contained tables and rules of thumb to make the calculation simpler. Even the residential heat loss calculation standard (CSA F280) still relies on tables for its methodology.

From its beginning in 1982, the R-2000 Program had an energy performance target as the benchmark for the standard. Calculations had to be done to determine whether or not a house complied. The personal computer also became available at this time, so HOTCAN was created, the foundation on which HOT2000 was developed.

HOT2000™

HOT2000 was one of the earliest computer programs to put the formulas together, making it easy to calculate the R-2000 energy consumption target. Over the years, HOT2000 has been updated and refined to become a very accurate simulation tool, and has been accepted as a code compliance tool in other countries. The core of the program is also being used in a number of specialized software versions.

HOT2000 is energy analysis and design software that takes into account the thermal effectiveness of the building and its components, the passive solar heating and the operation and performance of the building's ventilation, heating and cooling systems. It is designed for low-rise residential construction – essentially any residential buildings that can be built under Part 9 of the National Building Code of Canada. HOT2000 is the benchmark for testing compliance with the R-2000 Standard.

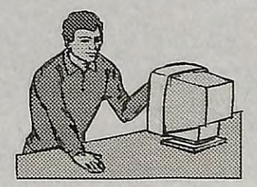
The latest version of HOT2000 (v 8.74) is the result of more than 15 years of effort supported by Natural Resources Canada's CANMET Energy Technology Centre. The software has become much easier to use. Its usefulness goes beyond just heat loss/gain calculations, as it can be used to optimize the design for the thermal effectiveness, help determine choice and placement of windows, as well as heating and cooling system performance to maximize energy efficiency. The software's accuracy has been tested and verified against actual houses.

Pull-down menus offer hundreds of input options for building design details, site and climatic zone. A graphical interface and a visual directory tree makes inputs simpler, and give direct access to specific ceiling, wall, floor, foundation and HVAC system screens. Frequent users can create house templates with default values of commonly used data to simplify creating new house files. Climate data for 75 Canadian and 200 US locations and selected centres outside North America are available. There is an additional option of creating user-defined weather files.

In addition to calculating if the house design complies with the R-2000 Standard, HOT2000 can be used to forecast the energy consumption for residential projects, project energy costs, calculate the optimum R-values for envelope components, improve the energy efficiency of building designs, and optimize solar heating at the design stage. It can be used to boost your standing as a designer and your profile as a builder of well-designed, energy-efficient homes.

Based on the characteristics of the house, HOT2000 can calculate the:

- space heating and domestic hot water systems for a range of heating systems, including conventional to high-efficiency condensing systems, air, ground and water source heat pumps, central air-conditioning systems with conventional or economizer controls, and primary and secondary domestic hot water systems
- heating and cooling loads for the house design for space heat system sizing, fuel consumption and costs
- effective R-value of envelope components, including thermal bridging of the framing materials in walls and attic ceiling structures



- effective R-value of windows, including glass type, fill type, spacer and framing, as well as a typical Energy Rating (ER) for each window type
- solar gains through windows in 8 cardinal directions as well as tilted windows, including skylights
- impact of central ventilation systems, including heat recovery ventilators (HRVs) and fans without heat recovery
- effect of air tightness on the energy use
- effect of various levels of thermal mass
- slab-on-grade, crawl space (open, ventilated or closed), basement and walkout foundations,

HOT2000 can provide much more information than many users need. Its full technical report for a house includes details on all elements entered, as well as tables of monthly energy profiles, energy consumption by device, space heating system performance, foundation temperatures and ventilation. Because reports can run to more than 14 pages long, they can be customized to provide only the information needed. If several options are being looked at, custom reports comparing results on up to four houses simultaneously can be created.

Other features include the ability to create house templates with commonly used values to speed data entry when creating new house files, fuel costs editors for established utility rates, as well as an economics editor for comparing energy conservation investment options between two houses.

Builders and designers can impress prospective clients with detailed energy performance calculations and the cost implications of design options. It can improve the attractiveness of the project to mortgage-lenders by showing the impact of reduced utility costs.

As with any software program, HOT2000 does require some understanding of basic assumptions to get the best results. Occasional users should plan to spend a bit of time to become familiar with the software before relying on it, or to get coaching from licensed R-2000 plan evaluators. However, HOT2000's help files are extensive and context-sensitive help is available at any point in the input screens.

HOT2000 is available in English and French versions. For information about HOT2000, contact Hot2000 Support at: *hot2000@nrcan.gc.ca.*

All the software reviewed above is available directly from The Buildings Group, CANMET Energy Technology Centre, Natural Resources Canada, Web site at *www.buildingsgroup.nrcan.gc.ca/software/software_e.html*
Fax: (613) 996-9909

HOT2000 v 9

A new version HOT2000 (v 9.01) has just been released, which includes refinements to the technical models used for calculation, including more accurate foundation and basement heat loss modelling. It also allows the modelling of six basement configurations in the same house, including walk-out basements in combination with other basement types, which was not the case in earlier versions.

Version 9 also is able to calculate room-by-room heat loss. However, the room-by-room analysis is not completely seamless and ongoing refinements are underway. In addition to the calculations done by the software, manual calculations still have to be done. Unfortunately, all the documentation is not yet completed for version 9, so experienced HOT2000 users will have to explore this version of the software before satisfactory calculations are derived. However, it can be used as an alternative to version 8.74 to do whole house heat loss calculations, and for R2000 compliance checks.

As with all other software, files are not backward compatible. This means that a file created in an earlier version can be updated to the later version of the software, but once done, the file cannot be read by the earlier version of the software.

HOT2®EC

HOT2EC is a tool for checking compliance with the Model National Energy Code for Houses. It allows for greater flexibility in innovative building designs by letting builders and designers to demonstrate that buildings that do not meet the prescriptive or trade-off methods in the energy code are still energy efficient. This analysis can be used to prove that the building will be as energy efficient as the same building designed using the prescriptive compliance requirements.

HOUSTRAD™

HOUSTRAD is an easy-to-use program that can be used to do trade-offs analysis with the energy code, or to look up thermal resistance values of building components. It automatically gives the user the prescriptive requirements for building components in their geographic region. Alternative component assemblies can be easily chosen from lists of components. The user can click on different assembly types and the program will automatically perform the calculations and give the building a pass or failure. HOUSTRAD was developed specifically for the Energy Code Trade-offs Compliance method.

HOT2®XP

HOT2XP is a quick and easy tool for analyzing energy use in residential buildings. Although its graphical interface is simple, the underlying analysis tool is the same as in HOT2000. HOT2XP is the software used by ***Energuide for Houses*** evaluators.

HOT2XP was designed to allow quick data entry by requiring only a small amount of critical information. It is suitable for modelling simple house designs. However, the user can edit many of the program's underlying rules and assumptions. The geometry of the house is derived from only a handful of inputs, and automatically calculates quantities such as wall and floor areas and volumes, which can be edited. By default, typical house characteristics are based on age and location, and the libraries of rules and defaults can be customized by the user.

HOT2XP generates fully detailed house files that may be read by HOT2000 version 8, so HOT2000 can be used to 'fine tune' or further enhance analyses that were started in HOT2XP. For more complex house designs, results will not be as accurate due to the simplifications used by HOT2XP. To maintain a high level of accuracy, the user may have to override many program defaults.

FRAME™plus

FRAMEplus is a software package for the detailed evaluation of thermal performance and condensation potential of any complex building assembly or product. It calculates the heat transfer, solar and visual transmission of any opaque or transparent elements, including windows, doors, walls, roofs, and below-grade assemblies. It can calculate the thermal bridging and the potential for surface condensation of opaque components. For effective results, users require special training. This is software for specialized users.

FRAMEplus and VISION are referenced by Canadian and American standards and workbooks and training courses are available. Windows analyzed by this software need not be laboratory tested for their thermal performance.

GS2000™

GS2000 is a software program for sizing loops for ground-source heat pumps (geothermal heat pumps) in both horizontal and vertical installations. The user can either input the monthly loads or use a simple residential load model. In simple menu-driven screens, the user selects or specifies soil, antifreeze and pipe properties and heat pump design information. GS2000 can predict the necessary heat exchanger size. It is equipped with online help for quick reference. The user can select units (inch-pound or metric) and language (English or French) preferences. The software includes ground temperature data for 129 locations in the United States and Canada.

Designers of ground source heating systems should be aware of GS2000, because it will help to correctly size ground loops and the amount of drilling or digging required. ☼

R-2000

For information on the R-2000 Program, contact your local program office, or call 1-800-387-2000 www.R-2000.ca

Solplan Review Back issues

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Quality First™ Software

Quality First™ is a simple Excel (v. 5) based software program designed for residential heating contractors. It is inexpensive, and intended for use with the Quality First Manual.

Quality First is a training program developed by the ***Heating, Ventilating and Cooling Industry Association of British Columbia*** (HVCI) for mechanical contractors to provide them with the guidelines for the professional installation of quality heating systems. The manual was developed for the training contains step-by-step worksheets which go through the process of sizing and designing a forced air furnace system. Heat loss calculations, furnace selection and duct system sizing are included. All calculations, charts and tables are in Imperial units.

Climatic data for both USA and Canadian locations is available. The software package includes three separate programs: heat loss/heat gain; duct sizing; and a job costing worksheet.

The Quality First Heat-loss/Heat-gain worksheet calculates room-by-room, floor-by-floor or whole house heat loss/heatgain for up to 28 separate rooms or areas. It includes a tutorial with examples and explanatory notes.

HVCI is a non-profit trade society established in 1993 to represent the interests of residential heating contractors in British Columbia, Canada. It is a contractor driven association with 75% of its membership made up of residential heating contractors.
More information: http://www.hvci-bc.com
Toll free (BC only): 1-888-774-8484 Outside BC: 1-604-414-0444

• Heat loss Summary Sheet with room-by-room cfm distribution and alternate (electric, gas fireplace, wood) heat source load calculations.

• Heat Gain worksheets incorporate features such as the ability to rotate the orientation of the house to eight cardinal points, shade coefficients, window coverings and automatic latitude adjustments factors.

• Appliance Selection Worksheet for selecting a properly sized heating appliance for the installation.

The Duct Sizing worksheet is designed for residential and light commercial installations (up to 5000 cfm, up to a 36x18 trunk duct). It includes a:

• *Supply Air System worksheet* to calculate trunk and run sizes either for room-by-room cfm requirements or by run size and number of fittings.

• *Return Air System worksheet*: Enter codes from Supply Air Worksheet for automatic calculation of Return Air trunk, run, drop and grille sizes.

Job Cost Worksheet: enter material & labour costs on the master and cost of each job is automatically calculated.

Quality First™ Manuals are available in a BC Edition or a National Building Code format.

Quality First Manual, Heat Loss/Heat Gain Software, and Duct Sizing Software is available in modules. The total package price is $ 324.00. For details, or to view software and manual pages check the HVCI web site. ☼

Roomxfloor

Roomxfloor is an Excel workbook that calculates heating and cooling loads on a room-by-room basis. It can be used for sizing heating and cooling systems, to design the heating and cooling distribution to individual rooms, and to balance the heating and cooling distribution systems delivery to individual rooms.

Roomxfloor was developed by Bruce Gough in Ottawa. It generally follows the CAN/CSA-F280-M90 approach, although it has some enhancements to improve the accuracy.

The description of rooms, walls, windows and other components is done floor by floor the same way that building plan drawings are prepared. A check is done of wall entries to ensure that no wall sections are accidentally left out and that each is dimensioned and oriented correctly. The thermal resistance and other characteristics of all ceilings, walls, floor, window and door assemblies are calculated automatically using sets of pull down lists. Changes to any user input, such as orientation, air leakage, ventilation characteristics, window sizes or assembly properties is instantly updated throughout the entire worksheet and reflected in the results.

The house may be rotated to any of eight compass orientations without changing any of the window data. The plan (and all the wall and window orientations) may be reversed by a single click.

Heating and cooling loads resulting from ventilation are calculated from ventilation rates with or without heat recovery. A ventilation rate calculator is provided which determines the rate of ventilation required by CAN/CSA-F326-M91, the principal fan requirements of the National Building Code 1995 and the Ontario Building Code 1997.

The calculation of heat gains through windows due to solar radiation considers the solar angle of incidence by latitude and time of day. This allows the calculation of transmission losses by refraction and an exact solution of the shading effect of overhanging soffits above windows and doors. The user may vary the time of day to determine the peak cooling load.

Roomxfloor is an Excel spreadsheet without macros, so users do not have to be concerned about the risk of viruses which can lurk in macros. It requires Microsoft Windows 98 (or later) operating system and Excel 97 (or later). ☼

roomxfloor

Information, and a review version of the software is available for download at www.roomxfloor.com. $ 99 from Energy Building Group Ltd., PO Box 72004, Kanata North PO, Kanata, ON, K2K 2P4

Japan's Building Regulations Concerning Volatile Organic Compounds

New Japanese building regulations that take effect July 1, 2003, will impose new testing and certification requirements for volatile organic compounds (VOCs) in building materials. They require that technical standards be developed to regulate air quality in "habitable rooms" (defined as rooms in residences, offices, restaurants, hotels, etc., where people are normally present) by restricting building materials that contain VOCs and by requiring ventilation systems in all buildings. As a result, materials containing chloropyrifos (a commonly-used termite retardant) can no longer be used inside habitable rooms.

The new regulations also require that all products be tested for formaldehyde by an approved evaluation body. A four-tiered formaldehyde emissions rating has been developed. Use of materials certified Class 1 will not be restricted. Materials certified as Class 2 or 3 will be subject to restrictions with regard to the total installation surface allowed. The use of products certified as Class 4 will be prohibited. This will apply to both domestic and imported products.

The new regulations are intended primarily to target indoor finishing products and built-in cabinets that have a significant surface area. They are not intended to cover interior trims such as moulding, handrails and door jams. Although the Japanese government originally wanted solid wood flooring to be covered by the regulations, it has since indicated its intention to exclude this product from the regulations, However, laminate and composite flooring is regulated.

Generally speaking, a number of materials used for interior finishing of a room or building (including substrata materials covered with permeable products such as carpet and wallpaper) must, as of July 1, be certified to a four-tiered formaldehyde emission rating. ☼

R-2000 Grease Filter Requirements in Kitchens

Natural Resources Canada (NRCan), has had several inquiries about the mandatory use of a grease filter on an HRV exhaust intake located in the kitchen in order for houses to be certified as R-2000. NRCan has issued a bulletin clarifying the technical requirement to deal with this issue.

The R-2000 Standard states that: "Any exhaust grille in a kitchen that is connected to an HRV or other exhaust device must be equipped with an accessible filter that is removable for cleaning without special tools." Although this statement leads people to believe that grease filters are mandatory, they are not a requirement for the certification of R-2000 homes provided they meet the requirements of the National Building Code, which states that "... A kitchen exhaust duct not equipped with a filter at the intake end shall be designed and installed so that the entire duct can be cleaned.". [9.32.3.10(5)]

However, NRCan believes that this is a good practice. As stated in the HRAI manual: "A grease filter should be installed in all kitchen exhaust ducts which are not accessible for cleaning for their entire length." ☼

Low-Flush Toilets

Sometimes we do things backwards. We spend a lot of money to treat and deliver clean drinking quality water to every household, then we flush most of it down the toilet where it has to be treated once more before disposal.

Toilets are the biggest consumers of water in the home. They are also a major load on municipal infrastructure, which is why more jurisdictions are mandating the use of low-flow toilets. In areas where water is metred, reducing water use also reduces the water bill.

Although there is a wide selection of six-litre toilets now on the market, despite CSA certification all low-flow toilets do not work properly and may actually use more water. Some use much more water. Others do not flush properly.

The city of Toronto has an initiative that offers residents a $60 or $75 cash incentive to replace existing high water use toilets with water efficient six-litre toilets. Disposal of old toilets is part of the program. The city did tests jointly with Canada Mortgage and Housing Corporation and the Canadian Water Works Association, and created its own list of approved toilets. (See table) The toilets selected were those that worked based on independent performance tests.

The criteria for Toronto's Toilet Replacement Program are that a toilet:

* flushes with 6.5 litres of water or less
* uses pilot-fill valves (ballcocks)
* handles variations in water pressure
* does not use adjustable floats to control closing rate of the flapper
* does not use a rubber flapper chain.

Do water efficient toilets really work?

A study by the American Water Works Association found that low-flow toilets do not require additional flushes to equal the performance of older, inefficient models. Daily flush patterns for six-litre toilets were identical to older models, but on average used 52 % less water per flush, saving up to 110 litres a day. Water efficient toilets that work have been re-engineered to function well with less water.

How do six-litre toilets work?

While six-litre toilets look similar to older models, their inner workings are designed to create a strong flush with less water.

Toilets with flappers

Six-litre gravity-type toilets with flappers have a redesigned bowl to enhance the siphoning action, which serves to pull the water out of the bowl.

Vacuum assist

Vacuum-assist toilets rely on gravity and a siphoning effect created by the bowl and tank design. Toilet tank water displaced during the flush exerts a vacuum pull to assist the force of gravity. The vacuum assist allows a greater area of the bowl to be covered with water, which means the toilet needs less frequent cleaning.

Toilets without flappers

Dual-flush technology is new to North America but has been used for decades in Australia, where only dual-flush toilets are allowed. This type of toilet has a dual flush that uses even less water than six-litre toilets. Liquid waste only can be flushed with three litres of water by pressing the half-flush button. Pressing the full-flush button will flush six litres of water to remove solid waste. Since this is a wash-down toilet, it has the largest trap size of any toilet - four inches in diameter.

Pressure-assist toilets use pressure instead of gravity to flush. The toilet has a container inside the tank that traps air, and as it fills with water, it uses the water supply line pressure to compress the trapped air inside. The compressed air forces the water into the bowl, so instead of the "pulling" or siphoning action of the gravity unit, the pressure-assist unit "pushes" waste out. Pressure-assist toilets usually have large water surface areas and trapways.

Tip-bucket technology is a new concept that uses a bucket at the top of the toilet tank. The bucket fills up with water, and when the lever is activated, the bucket tips the water into the tank. The advantage here is that there are no flappers to leak or to be replaced. ☼

Six Litre toilets that meet Toronto's performance expectations

American Standard toilets		
Model Name	*Model #*	Price Category:
Sonoma	*2454162.020*	$129 to $179
Sonoma	*2454562.020*	$149 to $199
Hamilton	*2092500.020*	$349 to $429
Ceralux/Vitra/Mancesa Toilets		
Vitra Atlantis	*6332 & 6330*	$99 to $120
Mancesa Cyclone	*2282W & 2281W*	$399
Eljer		
Eljer Aqua Saver Pressure Assist	*091-7025-00*	$420 to $630
Foremost		
Premier	*T-8207-WL& LL-8207-W*	$90
Kohler		
Wellworth	*K-3423-O*	$190 to $200
Santa Rosa	*K-3323-O*	$400 to 425
Mansfield		
Alto	*130-161*	$125 to $135
Niagara		
Flapperless	*N2216*	$200
Toto		
Reliance	*CST703TO4*	$190 to $260
Drake GMAX Flush	*CST744S*	$395 to $620
Ultimate Power Gravity Flush	*MS854114*	$450 to $770
Ultramax GMAX Flush	*MS854114S*	$650 to $980
Vortens/Lamosa		
GTA	*3411-O2-V & 3200-O2-V*	$125 to $140
Vienna II	*3406-O2-V & 3207 –02-V*	$125 to $140
Caroma *(dual flush)*		
Caravelle	*989646W; 989646B*	$700
Tasman 270	*989860W; 989860B*	$300
Caravelle 270	*989760W; 989860B*	$450

Prices are approximate only, to indicate the range of product that is available

More information:
http://www.city.toronto.on.ca/watereff/flush/install.htm
More information about septic systems and alternative on-site sewage treatment options can be obtained from The Ontario Rural Wastewater Centre at the University of Guelph http://www.orwc.uoguelph.ca/

New Hydronic Heating Standard

CSA B214-01 "Installation Code for Hydronic Heating Systems" is the new national code that provides the requirements for the sizing, installation, or alterations to hydronic heating systems. It covers boilers, circulation pumps, expansion tanks, radiant panel piping, pipes and fittings, system controls, hydronic space heating, radiant heating, domestic water heating and auxiliary systems.

CSA B214-01 is available from the Canadian Standards Association Sales Department, 178 Rexdale Blvd., Etobicoke, Ontario, M9W 1R3 (Fax 416-747-2475).

What to consider when choosing a six-litre toilet

- Trap Size. The number one concern regarding toilet performance is its ability to flush well without clogging. Larger traps are less likely to clog.
- Bowl Water Surface Area. Toilets with larger bowl water surface areas generally require less cleaning.
- Tank Lining. Lined tanks don't "sweat" during hot summer weather (although this is generally not a problem with six-litre toilets or if there is air conditioning in the home).
- Flappers. A flapper is the rubber device in the toilet tank. By pushing a lever, the flapper opens, and releases the water in the toilet tank down into the toilet bowl. The rising water level in the toilet bowl causes the toilet to flush.

Low-flush toilets and septic systems

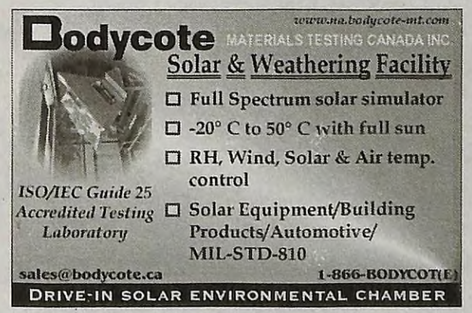
Do ultra-low-flush toilets work with septic tank disposal systems?

Septic systems require a certain amount of water to function properly. Concerns have been raised that there may not be enough water flow for proper septic system operation, and that low-flow toilets in those locations are not as important.

Dr. Chris Kinsley at the University of Guelph says that six-litre toilets should not pose a problem for septic tanks. Although reducing water flow will increase the detention time of the effluent in the septic tank, there will still be enough water from showers, the washing machine and other household water use for the septic system to function.

Did you know?

Moulds and fungi, which have a key role in the decomposition of organic material, make up more than 25% of the earth's biomass.



Designing Roofs for Snow

Canada is famous for being a winter country. Snow is a feature of the landscape. Quebec songwriter Gilles Vigneault starts his well-known song (and Quebec's unofficial anthem) with the words *"mon pays, ce n'est ne pas un pays, c'est l'hiver"* (my country is not a country, it is winter). Because winter is such a dominant presence in our life, and because many regions of Canada live from winter sports, one would think that building design appropriate for the climate and especially for snow loading would be well understood.

Unfortunately, that is not always the case. It seems that in the pursuit of cute, picturesque designs, many planners and designers are forgetting about basic fundamentals. This has been especially problematic in Whistler, BC, where problems have been observed with complicated roofs, which include gables and mid-slope obstructions. Architectural features designed into roofs often compound the effects of high snow loads.

Due to the number of problems that have arisen, the Resort Municipality of Whistler has teamed up with Levelton Engineering of Vancouver to create a Web site that serves as an information exchange for roofers, building professionals, and the general public interested in building science and the effects of snow load on roof design. The goal is to develop guidelines for the design and construction of roofs in high snow load climates.

Snow Management Strategy

There are only two strategies for the management of snow on an alpine roof: snow shedding and snow retention.

Snow Retention

A snow retention design incorporates features such as a low pitch roof and high-friction roofing material such as shingles.

Snow retention roofs

Roofs designed to retain the entire snow load are very common in the European Alps. Snow retention is a time-honoured solution to managing snow roof load. That is not the case in North America except for flat roofs.

The flat roof is the simplest roof profile for managing snow. It avoids all the problems associated with a roof slope such as ice damming and snow creep, as long as a good waterproofing membrane has been installed to prevent the ingress of melt water. Silver Star Resort near Vernon, BC, is one development that has encouraged a flat roof, snow retention approach.

More common in Alpine regions, especially in Austria and Switzerland, is the simple peaked roof. This roof typically has a shallow pitch (not more than 5 in 12) and uses a high friction shingle or shake. Snow fences are sometimes used around the edges of the roof in problem areas to prevent unplanned movement and problems associated with unplanned snow shedding. The main advantage of retaining snow is that the snow load is predictable and can be calculated based on typical ground snow loads. The simplicity of the roof plan also allows strong framing to be built in to support the roof loads. Another advantage of this simple approach is that there are few lateral forces or impact loads imposed on the roof due to snow movement.

In a typical Austrian villa, chimneys and other obstructions are installed at the peak of the roof where the shear loads are minimized, thus preventing damage in the case of an extreme snowstorm.

The National Building Code of Canada divides the snow load on a roof into two components: a snow load and a rain load. The rain load is typically not more than the snow load on the roof, but needs to be considered in the structural design, as the added load of the rain can be significant. Also important is snow drifting and melting, both of which redistribute the snow load unevenly.

Roofs designed to retain snow can incorporate many of the features that North American designers want to include, such as dormers. However, the dormer on a snow-retaining roof does not prevent snow from accumulating in front of doors and windows. The snow-retaining roof offers the designer freedom to design an aesthetically pleasing roof incorporating obstructions to snow movement that actually increase its effectiveness.

Snow Shedding

North American designers have tended to adopt the snow shedding strategy. While this strategy is sound, it must be carried out properly to ensure that it works. A snow-shedding roof must have few barriers to snow movement.

Roofs designed to shed snow must be steep. They must have a roof pitch steeper than 5 in 12 and as steep as 12 in 12. Most often snow-shedding roofs use low friction vertical standing seam metal roof panels. The standing seam does direct the snow movement. However, snow movement is the primary cause of all performance issues related to snow-shedding roofs.

A snow-shedding roof strategy can also be a risk to public safety due to falling snow and ice.

The use of inconsistent design elements is the biggest problem with snow-shedding roofs. North American designers add architectural design elements such as gables, valleys, chimneys and high friction shingles that obstruct snow shedding. Snow-shedding roofs may actually offer the designer less freedom than snow-retention roofs, because obstructions to snow movements need to be kept to a minimum (chimneys should be at the peak) and valleys and gables should be avoided.

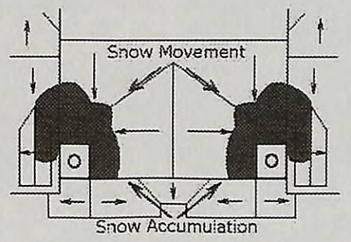
To control locations where shedding of snow occurs, dormers are usually designed over entrances to prevent snow movement from blocking the entrance, while the pitch of the roof and the roof material are intended to shed snow. A failure to consider the impact of the dormer location in a shedding strategy is the primary cause of damage to the roof.

Dormers create valleys and performance problems. If the roof design does not take into account the potential of snow accumulation in valleys, damage may occur to the structure below. If snow locks in a valley or behind an obstruction on a steeply pitched snow-shedding roof, the snow may eventually begin to creep once enough snow has accumulated above the locked mass. Snow creep can add enormous loads to the roof structure. In many cases, snow creeping down a valley has resulted in the bending and flattening of standing seams. It can even cause structural failure.

Ice Damming

Ice damming occurs when snow on warm portions of a roof melts. The heat that melts the snow typically escapes from the interior of the building through the attic and out the through roof.

As the heat melts the snow, melt water flows down the roof slope to the eaves. Usually the eaves have been built to overhang the building, and are thus quite cold. Water from snow melt freezes at the eaves and begins to accumulate, forming icicles and creating a dam that obstructs the flow of water. Roofs rely on gravity for positive drainage, but ice dams can cause water to flow back up the roof. As the ice dam builds, melt water ponds behind it and enters the roof through fastener penetrations and seams. Once the water has breached the integrity of the roof, the potential for damage (ranging from staining to rot) can be significant. ☼



Chimney placement on this duplex results in a large mass of snow accumulation behind the chimney chase. Snow funnels down from the valleys caused by the opposing dormers and locks behind the chimney.

Back up of snow onto and over the lower gable and up onto the upper roof. The piles of snow on the ground are partially due to avalanches from the roof when the weight of overlying snow exceeds the cohesion.

The same roof modified. Snow now accumulates on the top portion of the roof and sheds from the bottom. The retention of the snow reduces the potential for locking on the lower roof and the impact of avalanches from the upper roof when cohesion is exceeded.

More information: *www.levelton.com/whistler/snow/snowhome.html* Use Microsoft Explorer (only) to get clear access to the site. An interactive forum will be added to the site for discussions on methods and practices in dealing with roofing problems in high snow-load climates.

Energy Star Specifications

Energy Star is the U.S. Department of Energy marketing program for improved energy performance. Energy Star is a simple to understand labelling approach for a wide range of energy consuming appliances. It covers office equipment, consumer electronics as well as residential appliances and heating and ventilating equipment.

Energy Star labelled products are the most efficient products available. Because of the integration of the North American economy and since many products are marketed on both sides of the border, NRCan has entered into an agreement with the US DOE to administer Energy Star in Canada.

We are highlighting the specifications for meeting Energy Star to standards for selected equipment builders may encounter.

Appliance/Equipment	Energy Star requirement
Air-Source Heat Pumps	7 HSPF/12 SEER *(15-20% more efficient than the minimum federal efficiency standards).*
Gas Furnaces	90 AFUE *(about 15% more efficient than the minimum federal efficiency standards).*
Residential Boilers	Must meet or exceed 85% AFUE
Programmable Thermostats	Capable of maintaining at least two separate programs *(to deal with the different comfort needs on weekdays and weekends)* and at least four temperature settings for each program.
Residential Ventilating Fans	Range hoods (up to 500 cfm) minimum level of 2.8 cfm/watt Bathroom & utility room (to 75 cfm) minimum level of 1.4 cfm/watt Bathroom & utility room fans (more than 76 cfm) minimum level of 2.8 cfm/watt.
Residential Ceiling Fans	At low speed: minimum airflow of 1250 cfm and efficiency of 155 cfm/watt. At medium speed: minimum airflow of 2500 cfm and efficiency of 110 cfm/watt. At high speed: minimum airflow of 5000 cfm and efficiency of 75 cfm/watt.
Geothermal Heat Pumps	Open loop - heating: more than 3.6 COP; cooling: more than 16.2 EER Closed loop - heating: more than 3.3 COP; cooling more than 14.1 EER Direct expansion - heating: more than 3.5 COP; cooling: more than 15 EER
Clothes Washers	A modified Energy Factor of 1.26 or more. Typically, clothes washers with an EnerGuide energy consumption rating of less than 470 kWh/year
Dishwashers	An energy factor of 0.58 or greater. At least 25% more efficient than the minimum federal energy efficiency standard. Typically, dishwashers with an EnerGuide energy consumption rating of less than 565 kWh/year
Refrigerators, Freezers and Refrigerator-Freezers	At least 10-20% more energy efficient than the minimum federal standards (depending on size and configuration).
Compact Fluorescent Lights	Input voltage and frequency: 120 volts (V), 60 hertz (Hz). Power factor: 0.5 or higher. Operating frequency: greater than 40 kHz

Technical Research Committee News

Canadian Home Builders' Association

Mould

Builders have identified a need for practical, hands-on guidelines on how to avoid mould problems and how to deal with them should they occur in new houses. Much work has already been undertaken by CMHC in regards to investigation of the issues and remedial steps that can be taken, especially for existing housing. CMHC has several consumer pieces dealing with this.

Relevant information pieces will be identified and put together into a list. For the longer term, CHBA sees mould issues as part of a larger "health in housing" issue. CHBA wants to see a coordinated approach by the various federal departments and agencies involved to help address these concerns.

In essence, mould control is an issue of moisture management. Manage moisture effectively, and mould should be kept in check.

National Building Code Change Review

Consultation on proposed changes to the National Building code is now underway. It is being done jointly at the national and provincial/territorial levels, so that all comments will be reviewed at the same time. As a result, by the time the next edition of the code is ready, it should be ready for speedy adoption by all jurisdictions, without further review. Proposed changes have been posted on the national codes centre web site, *www.nationalcodes.ca*. Links are provided on this site to the provinces that have a local review process, or that may have some province specific changes. (This applies to BC and Ontario.)

The period for comment ends April 15, 2003, so anyone with concerns, or wanting to see how they may be impacted by any of the changes should do so immediately. In the January 2003 issue of Solplan Review (No. 108) we highlighted the significant changes proposed to Part 9 (Housing and mall Buildings Section).

While there are a total of more than 1300 changes, many are minor editorial comments. However, there are a number of significant changes, and these need to be reviewed. Although the code is moving towards a new objective-based format (which is also posted on the web site), a revised version of the existing code will remain as a document that will provide guidance for those who do not wish to pursue the proposed new approach.

Major changes include new requirements for building envelope construction (to keep the rain out) and mechanical ventilation.

Foil-backed Insulation

Concerns about the improper use of foil backed (radiant barrier) insulation products has been an ongoing issue for a while now. Some people are spreading misinformation about where and when these products can be used. CHBA has put some information on this topic on its web site and will follow up with CMHC on possible research on the performance of this type of product when used improperly.

In the May 20023 issue of Solplan Review (No. 104) we reviewed the physics of radiant heat flow and low emissivity products.

Information Road Map

CHBA has revised the Technical Research Committee web page on the CHBA web site (www.chba.ca). The new page includes a section entitled "Problems and Solutions" which gives an opportunity for members to report solutions to problems that they have experienced. Members are encouraged to visit the site by logging into the "Members Area," clicking on the "Committees" button and then clicking on "Technical Research Committee" highlighted text.

Building Official Representation on TRC

In order to keep lines of communication open, and to strengthen the relationship between building officials and the industry, CHBA has invited a building official representative to sit on the TRC.

The Housing Industry's Environmental Record

CHBA has released a new brochure highlighting the housing industry's performance on reducing green house gas emissions. Copies are available from CHBA National Office.

The Technical Research Committee (TRC) is the industry's forum for the exchange of information on research and development in the housing sector.

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Letter to the Editor

Re: Energy Answers, Solplan Review (No.108, January 2003).

Solplan Review is one of my favourite sources for good building science discussions.

I was delighted to see Rob Dumont's thorough and practical review of integrated design processes (IDP) in the January issue. For those not familiar with the subject, there is an enormous amount of information to absorb and, over the past few years of promoting C-2000, I have seen many pairs of eyes glaze over. I hope the following supporting comments to Rob's column will help readers understand the process more clearly.

Although IDP has been developed in the context of commercial buildings, the same principles apply for detached residential projects. House projects don't have the same problem of coordination with many consultants, but they still need to coordinate the work of different trades, as most of the thinking is done at the trades level and not by consultants.

A good example of IDP at the trades level can be found in an article in Fine Homebuilding last year. ("Building Affordable Houses" by Fernando Pagés Ruiz, Fine Homebuilding magazine, February/ March 2002.) A principal organizing idea with IDP is that no part of the work is taken on without considering the information of all related tasks that influence its own requirements. This has meant in practice that, for energy consumption and thermal comfort issues, the design proceeds with real-time support from energy simulation, which provides performance numbers to support decisions on selection of insulation levels, windows, and equipment (furnace) sizing. Use of energy simulation during the early stages of design has been the key to the success of the C-2000 Program. Energy simulation is not a skill that every builder team has, but new tools are now available that make simulation more accessible. Commercial projects use variants of the DOE-2 computer program such as EE4.CBIP, but at the very early design stage the CBIP Screening Tool is often all that is needed. It is a Web-based tool accessed at *http://cbipscreen.nrcan.gc.ca.*

The R-2000 Program demands HOT-2000 simulations, which require detailed take-offs done with specialist assistance. A quick entry version of HOT-2000, called HOT2-XP, is now available. This user-friendly version can be downloaded from: *http://buildingsgroup.nrcan.gc.ca/software/hot2xp_e.html*

Following the idea of acting from a position of knowledge, IDP involves the concept of iterative development. However, the idea of repetitive steps during design is a concern since every option takes time and money in development. Setting design goals at the outset is essential but, in some cases, the integration of disciplines reveals that the established targets can be easily exceeded and a new, more advanced target may be appropriate.

How does the designer know where or when to stop? The saving concept is that of convergence. In any iterative development process, repetition is applied until all answers start to converge on an optimum position. By moving through the large-scale issues to the small scale ones, the iterations are directed and in turn constrain the total possible responses. This idea is seen in the position of assessing heating and cooling needs in the C-2000 Process Guide software. Heating and cooling loads are calculated only after the preliminary concepts for the following have been discussed and agreed on:

- orientation & massing,
- envelope performance,
- window to wall area proportion,
- window thermal performance values,
- daylighting objectives,
- lighting design,
- electrical power, and
- ventilation requirements.

All of these design elements have an impact on how much heating or cooling from boilers or chillers will be required. As Rob identifies in his article, using IDP in design is a significant change to our status quo ways. The benefits, however, are spectacular. Better facilities, cheaper operating costs, longer lasting and higher asset values ... Even more fun on the job! Thanks for starting the discussion on integrated design processes. Keep up the good work.

Stephen Pope, OAA, MRAIC
Natural Resources Canada,
CANMET Energy Technology Centre
Buildings Group, Ottawa

Using DNA Analysis to Detect Water Damage in Wood-Frame Construction

by Jonathan Moran

Wood-rotting fungi are the major cause of wood deterioration in Canada. Although fungal spores are found everywhere, they require moisture to germinate and grow. In a well-designed, built and maintained wooden building, moisture levels do not remain high enough for long enough to allow the fungi to establish a foothold. However, if the building envelope failure allows the moisture content of the wood to exceed fibre saturation (about 28%) for long enough, wood-rotting fungi may germinate, grow and begin to undermine structural integrity. Once the fungi are established, they can remain dormant for long periods of time should the wood dry out. If the structure is subject to re-wetting, the rot will continue as before. A vital step in the remediation of water-damaged buildings is the identification of the extent of the damage. The envelope specialist has several tools available to help in this process, including visual inspection, the pick test, moisture probes, and thermography.

What has DNA analysis got to do with any of this? We are all aware of some uses of DNA analysis already, such as genetic fingerprinting in criminal cases or paternity testing. However, there's more to it than that. Each organism has its own unique genetic signature, and if the signature is identified, then the organism can be detected. Of course, there's the matter of scale; very few of us would need DNA analysis to tell us that there was an elephant standing on their foot, but for smaller organisms, the technique comes into its own. For example, the presence of wood-rotting fungal DNA within a sample of wood from a suspect building is a fairly good indicator that there is a problem with water ingress. DNA analysis can thus be used as a surrogate moisture meter.

How does the test work? A sample of the wood is taken using a small metal auger (¼" internal diameter). All DNA within the sample is extracted, and any fragments corresponding to the genetic signature of wood-rotting fungi are identified.

With all the other tools already available, why use DNA analysis? For a start, it's extremely sensitive; identifying water damage before it is visible to the naked eye or has caused enough structural damage to be detected by the pick test. Secondly, it's very accurate, since the test responds only to wood-rotting fungal material within the wood itself – not, for instance, to spores on the surface of wet studs, or to sap stain fungi which cause no structural problems. A third advantage is that, since the test is so sensitive, only a very small sample is required. As a result, there is minimal visual and structural impact on the building. However, perhaps the greatest advantage is that, unlike moisture meters, DNA analysis detects water problems even if the wood is dry at the time of inspection. This is because the fungal DNA remains in the wood when the organism is dormant, and can be found even if the fungus has died. Thus, whereas moisture meters may fail to detect a problem during dry, summer months, DNA analysis can safely be employed year-round. ☼

Jonathan Moran is president of Axon Industrial Diagnostics Inc. in Victoria, BC, a company that specializes in wood rot detection. He can be reached by e-mail at: jmoran@axonid.com

The Costs of DNA Testing

A DNA analysis is not the ultimate cure-all test, but it is another diagnostic tool that many may not be aware of. A DNA analysis costs about $48 for a test, based on a minimum number of tests. It's more suited to a larger building, such as a multifamily building, or a large single family house.

The number of tests needed to get a decent picture of the extent of water damage will depend on the specific circumstances. The technique is especially useful for areas in which the investigator feels there is likely to be a problem based on previous experience, but where there is no evidence of moisture using conventional methods such as moisture meters. It also allows estimation of the extent of damage such as in a structural beam supporting a balcony, so that decisions on whether or not the whole beam needs to be replaced can be made before rehabilitation work starts.

The technique is not specific to a climatic region. It will work anywhere that wood-rotting fungi are a problem. In areas with lower rainfall, dry rot (Serpula lacrymans) becomes a bigger problem, and that can also be identified by DNA testing.

Energy Answers

Rob Dumont

Like many other people with programmable thermostats, I set the house to a cooler temperature (15°C) during the night hours and unoccupied daytime hours. So here is the thought I have: The time and energy used to raise the temperature up to room temperature (20°C) from the lower temperature is a fairly long period. Is there a better temperature to use as the low point that is more efficient? Does the time it takes for the temperature to drop to 15°C equal the time it takes to raise the temperature back up? Would I save nearly as much if I set the low point to 16°C? How much do I save over a day or a week for each degree dropped? I live in Ottawa.

I'll deal with each of your questions in the order posed, but, in general, using a programmable thermostat is one of the most cost-effective ways to reduce space heating energy costs in residences. Programmable thermostats can be purchased for about $50 to $100 and, depending on the climate zone, can save a considerable amount of energy. The colder the climate, the greater the absolute energy savings that temperature set-back can achieve, as the heating season is longer.

Is 15°C the best set-back temperature to use?

In general, the lower the set-back temperature the better in terms of reaping the greatest amount of savings from a programmable thermostat. Having said that, however, one must be careful about not cooling the house to such an extent that the window surfaces and the temperatures in the closets in bedrooms become so cold that condensation can occur. With condensation comes water, and with water mould often follows. That is why one should be careful in colder weather about reducing the temperature too low.

I once lived in a house in which I set the temperature down to as low as 10°C during the unoccupied time. One problem I noticed was that in colder weather the windows would frost up and have condensation on them, and this often leads to mould which is very undesirable. Another concern is that if you have a very leaky older house — one with poor air-tightness —some of the water pipes in certain areas of the house may actually freeze. The lower part of the house often will have the greatest amount of cold air entering it, and frigid air on a bare pipe can freeze water fairly quickly. This also happened to me.

For most houses, 15°C is probably a good set-back temperature. If you have a well-insulated and sealed house, lower temperatures can be used. If you have a leaky, poorly insulated house, be very careful about setback in below-freezing weather.

Does the time it takes for the temperature to drop to 15°C equal the time it takes to raise the temperature back up?

The quick answer is "No." The time that it takes to drop the temperature depends a lot on the outdoor temperature, the quality of the building envelope that you have, the thermal mass inside the house, the amount of internal heat gains (from lights and appliances), and the solar gains. In very cold weather, a house will drop to 15°C a lot faster than in warmer weather. The time that it takes to raise the temperature back up depends on the outdoor air temperature, but also on the size of the furnace or heating system, as well as the quality of the building envelope, the amount of thermal mass inside the house, and the solar and internal heat gains. In general, a larger heating system will be able to raise the temperature more quickly.

Would I save nearly as much if I set the temperature back to only 16°C?

You say that you are in Ottawa, which has a relatively long heating season, and in general you would not save as much energy if you only drop the temperature to 16°C.

How much do I save over a day or a week for each degree dropped?

The effectiveness of a set-back thermostat in reducing heating bills depends strongly on your location. I once lived in Nairobi, Kenya, where the outdoor design temperature for sizing heating systems is +10.8°C. Only a few people had heating systems. In that climate, a 5°C set-back would give you almost 100% saving on your annual heating bill. Here in Saskatchewan, a 5°C set-back for 12 hours a day would only give you about an 8% saving on your annual heating bill. The warmer the climate, the greater the percentage saving you reap from set-back. However, in colder climates, set-back works for more days of the year so you get a greater value in terms of absolute energy savings. Because of the strong dependence of energy savings on the local climate, one cannot give a universal answer as to what you will save using a programmable thermostat. However, in all locations in Canada, a set-back thermostat is an excellent choice. I would estimate that reducing the house temperature in Ottawa by 1°C for 12 hours a day would save about 2% on your heating bill. A 5-degree set-back for 12 hours a day would save about 10% on your heating bill.

If you air-condition your home, a good programmable thermostat can also be used to "set up" the temperature during unoccupied hours in the summer period.

For a good survey of programmable thermostats on the market in North America, have a look at the January 2001 issue of Consumer Reports. ☼

Rating Gas Fireplaces

By the summer of 2003, all gas fireplaces sold in Canada will have to be certified for energy efficiency and have an EnerGuide rating to help consumers make energy-wise choices.

Regulations to be proposed under Canada's Energy Efficiency Act will specify that gas fireplaces sold in Canada must be tested to the new Canadian Standards Association CAN/CSA P.4 Test Method for vented gas fireplaces. The results must be certified by a verification agency accepted by Natural Resources Canada (NRCan).

The Heating, Refrigeration and Air Conditioning Institute of Canada (HRAI), the Hearth, Patio and Barbecue Association of Canada (HPBAC) and NRCan will work with manufacturers and importers to develop an industry-led rating program based on the EnerGuide program.

These new requirements will help ensure that consumers can identify the most energy-efficient gas fireplaces in the marketplace. Energy efficiency is the most cost-effective way to meet the long-term demand for energy while reducing the production of greenhouse gas emissions that contribute to climate change.

NRCan also proposes to publish a directory of gas fireplace efficiency ratings in a format similar to the EnerGuide Ratings for Major Household Appliances.

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Should You Get Your Heating Ducts Cleaned?

Duct cleaning has become a big industry. As a homeowner, you may be regularly solicited to have your heating ducts cleaned. Claims are made that duct cleaning will:

- provide you with a better indoor air quality
- reduce the presence of house moulds and allergens
- get rid of dust
- result in more airflow and better delivery of warm air, and/or
- reduce energy costs

If you expect duct cleaning to make these improvements, you may be disappointed. It is difficult to find objective and independent research to substantiate these claims. Researchers have observed little or no difference in the concentration of house airborne particles or in duct airflow due to duct cleaning.

Duct cleaning may be appropriate if there may be construction debris or other build up in ducts. This should not require regular cleaning.

Do not accept offers from duct cleaners to spay or "fog" the ducts upon completion of the work, ostensibly to get rid of residual bacteria or mould. There are no products registered in Canada for residential duct cleaning. A proper duct cleaning job does not require the use of a biocide to clean up missed areas.

From: CMHC About Your House fact sheet: Should You Get Your Heating Ducts Cleaned?

Concepts of Fire Risk Assessment

By David Yung and Noureddine Benichou

With the move towards performance-based design and objective-based codes, the level of fire safety that is provided by a proposed fire safety design will need to be evaluated. Fire risk assessment is a methodology that can be used to evaluate the performance of fire safety designs. It gives a quantitative assessment of the level of fire safety that is provided by an installed fire protection system and thus allows a rational assessment of whether the fire protection is adequate.

To evaluate the expected risk to life to the occupants in a built environment, a comprehensive fire risk assessment can be expressed by the following equation:

$$\text{Expected Risk to Life S} = \sum_i (P_i \cdot C_i)$$

where S represents the summation of all probable fire scenarios, P_i is the probability of a fire scenario and C_i is the expected number of deaths as a consequence of that fire scenario.

Structuring Fire Scenarios

To show how fire scenarios can be structured, we can take the very simple case where a fire occurs at the only exit door of a room with a few people inside. Assume also that the fire develops into a whole-room fire and all the people in the room die as a result of the fire. The risk of this simple fire scenario is the probability of a fire occurring at the only exit door of a room multiplied by the number of people who die as a result of the fire.

Obviously, fire risk assessment is not as simple as that. There are normally fire protection measures to control the development of a fire and also to prevent it from spreading to other parts of a building. There are also normally fire protection measures to give early warnings to the people and to help them get to a safe place before the fire spreads. Therefore, risk assessment includes the assessment of the failure of these fire protection measures, so as to determine the expected risks to the occupants and the property.

A more realistic fire scenario can be considered to consist of the following five sequential events.

1. Fire ignition, based on all probable occurrences in a particular setting, such as cigarette ignition of a couch in a living room or a mattress in a bedroom. Prevention education would reduce the probability of occurrence of this event and the consequential risks.
2. Fire growth, based on all probable developments of a fire, from smoldering to flashover fires. Fire protection systems such as sprinklers, compartmentation and door self-closers can help to contain these fires and reduce their consequential risks.
3. Smoke spread to critical egress routes and other locations in a building where people are. Fire protection systems such as smoke control, stairwell pressurization and door self-closers can help to contain the smoke and reduce its consequential risks. The reduction in risk depends on the reliability and effectiveness of these smoke control systems.
4. Occupants are trapped as a result of the spread of fire and smoke to egress routes. Fire protection systems such as fire alarms, voice communication, protected egress routes and refuge areas can help to provide early warning to occupants, and to direct them either to evacuate the building or to seek refuge in certain areas. The reduction in risk depends on the reliability and effectiveness of these early warning and evacuation systems.
5. Fire department fails to respond or fails to respond in time. Proper notification procedures and adequate fire department resources would help to rescue the trapped occupants and control the fire. The reduction in risk depends on the reliability of notification procedures and adequacy of the fire department resources.

Except for the occupants in the room of fire origin, all of these five events must occur before a fire can cause harm to the occupants. Fire protection systems that are installed to prevent each event from happening can be viewed as a barrier in each event. Hence, there could be potentially five barriers, as shown in Figure 1, and the risk to the occupants depends on the combined effectiveness of these barriers. For example, if there is no barrier in each event, the risk to the occupants is 1. If there are five barriers and each barrier has a failure rate of 0.5, the combined failure rate, or the risk to the occupants, is 0.03125. Alternatively, if there are only two barriers and each has a failure rate of 0.1, the risk to the occupants is less, 0.01. This is the reason why risk assessment is not just based on what fire protection systems are installed, but rather how effective they are.

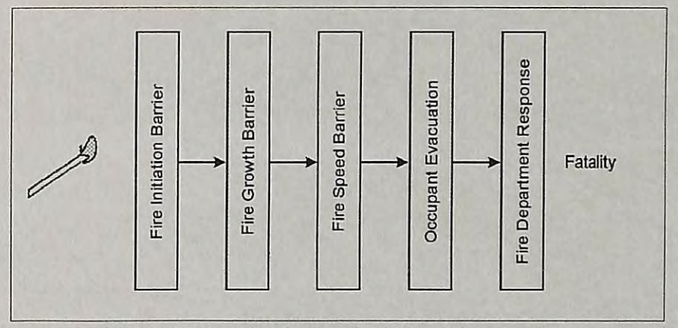


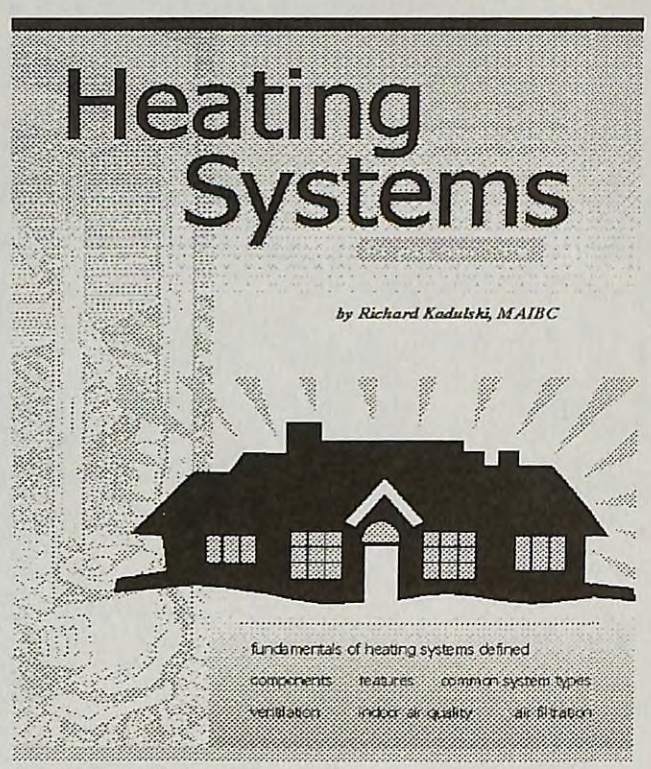
Figure 1. Potentially there can be five fire barriers between fire source and fatality.

How to calculate the failure of each barrier, or the failure of the fire protection systems, is the essence of risk assessment. It involves the time-dependent calculations of fire growth, smoke spread, occupant evacuation and fire department response. Time is important because if occupants can get to a safe place before untenable conditions develop in the egress paths, there is no risk.

We will use a simple example to show why time-dependent calculations are needed. We will look at house fires and conduct a simple risk assessment to examine why most fire deaths occurred in house fires. Based on fire statistics, the most frequent fatal fire scenario in house fires is the one that involves the ignition of a couch in the living area. That means barrier one is not there and fire ignition will happen with a certain probability. Secondly, most houses don't have sprinklers or walls, including closed doors, to contain the fire in the living area. Therefore, barrier two is not there and fire will grow with certainty. Thirdly, most houses don't have a smoke control system to prevent the smoke from spreading to the whole house, including any egress paths such as stairs. Therefore, barrier three is not there and smoke will spread with certainty. Fourthly, houses usually have smoke detectors to give early warnings. However, it is effective only if it works and only if it can give warnings early enough so occupants can have enough time to escape. But fires involving upholstered furniture can be very fast, developing into flashover fires in just minutes. That is why the time factor is of essence in fire risk assessment. If the occupants can escape before the fire develops into a flashover fire, then barrier four is there. Otherwise, barrier four is not there and the occupants are trapped in the house. Then their safety depends on the response of the fire department. If the fire department can respond quickly, then barrier five is there. Otherwise, barrier five is not there. In short, the only defense in house fires is barrier four and five, and they are effective only if they work and if they work very fast against fast fires. That is why house fires are deadly because there are not enough barriers to protect the occupants.

For other types of occupancies, such as highrise apartment and office buildings, there are usually more fire protection measures and therefore more barriers between the fire and other occupants. For example, there is usually compartmentation (barrier two) to contain the fire, sprinkler protection to control the development of a fire (barrier two), and smoke control systems (barrier three) to limit the spread of fire. With more barriers, fire risk assessment becomes more complex. ☼

Dr. David Yung is a former senior researcher in the Fire Risk Management program at NRC's Institute for Research in Construction. Dr. Noureddine Benichou is a senior researcher and leader of the fire risk assessment group in the same program.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